

Peru



The Plaza de Armas or Plaza Mayor in the historical centre of Lima. Photo credit: ©iStock.com/Holger Mette.



"The challenge of the future of Peru will be decided in its cities. Old urban societies learned to care the gift of water, as well as Caral, Cuzco, Macchu Picchu, Kuelap... Today, our cities turn the rivers into sewers. Alluvial cones and channels are occupied by housing. The uncontrolled waste of water reflects the lack of solidarity among ourselves and with nature. In spite of possessing 4.6% of the world's surface water, social inequalities and pollution make urgent a sustainable urban water management"

Urban Water Supply in Peru

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Abstract

After outlining the engineering works and expertise of the ancient Peruvians in securing water for their cities, this chapter describes the status of urban water in contemporary Peru. It focuses on the Metropolitan Region of Lima-Callao, which, despite concentrating a third of the country's population, still has approximately 11% of its population without access to water and 16% without access to sanitation. It emphasizes the gaps between the peripheries of poverty and the centers as regards access to and continuity of service and rates. It details the links between lack of water and sanitation, waterborne diseases and quality of life. Another two cases of cities are studied: Cusco, the "navel of the world," with its extremely deficient water system and vulnerability to disaster risks, and Iquitos, the capital of the Peruvian Amazon. Lastly, the chapter shows how despite certain institutional strengths, the water and sanitation sector still presents serious problems (such as political instability, lack of continuity, limited human resources) and requires more sustainable water management as part of a green economy to provide equitable access and quality in water services and resources. Hence the importance of launching an integrated urban water management process to properly combine the 5 "Is" of management (Integration, Investment, Information, Institutions and Infrastructure) in order to achieve and sustain water security and consequently urban sustainability.

1. Introduction

The world's 20th largest country, with an area of 1,285,000 km², Peru experienced significant urban growth during the second half of the 20th century. Nowadays, 76% of a population of 30,814,175 live in urban areas and 24% in rural areas (INEI, 2014).

The link between the social collective, organized by the authorities of the ayllus and the State, composed of a hierarchy of curacas remained as the social and political system from the Caral civilization until the end of the Inca Empire.

Ceremonies, rituals and offerings were periodically organized for the earth and water out of gratitude for the benefits received from them as the deities that permitted the survival and continuity of their social system. On the coastal strip, they dug in the sand and built “sunken farms” to take advantage of the moisture in the soil. Meanwhile, in the flooded zones or wetlands, in some cases they built raised fields or ridges whereas in other settings, they drained the land through ditches or drains, channeling the water into reservoirs or huachaquas.

The inhabitants of the valleys implemented fields irrigated by a canal system administered by basin. Productive lands were respected and urban centers or dwellings located on unproductive terraces and specially conditioned spaces on the hillsides. In the hilly, rocky Andean space, with very little productive land, the inhabitants built terraces on the slopes or constructed platforms on the rough slopes, with a corresponding system of irrigation canals.

An advanced geohydrological management system was provided by amuna technology, implemented in the central coast valleys and rivers with a low or temporary flow. These measures solved the water shortage problem. Water was “sown” in the

High Andean territory by channeling it from the lagoons to geologically permeable places into which it filtered, and was subsequently extracted in springs or puquios, dug at regular intervals throughout the basin. Similar technology was used on the south coast through “infiltration galleries.” This extraordinary water management system made it possible to supply the citadels, characterized by having tanks and wells. Thus Chan Chan was supplied by water from over 140 wells (Tavera). Although the area where Cajamarquilla is located is now completely dry, a city that size obviously required a continuous, copious water supply, both for everyday use and

Figure 2. Huachaque (left) and excavated puquios (springs of water, right)



Photos: Ruth Shady

Figure 1. Five thousand years ago, the populations in Supe Valley on the north-central coast of Peru had already achieved productive, agricultural and fishing conditions. A complementary agricultural-fishing economy supported the formation of the Caral civilization, the oldest on the continent (dating back over 5,000 years). Photo: R. Shady



for building adobe bricks, the technique of choice for pyramids and buildings. Studies conducted by Mogrovejo and Makowski (1999) conclude that at one time the Huaycoloro River carried water permanently, as borne out by the canals and reservoirs located in Cajamarquilla (Tavera).

Likewise, when they built the city of Machu Picchu (2000 440 m), the Inca were confronted with extremely steep slopes. They managed to gain access to water by pinpointing the exact location of the source and determining whether it would meet the population's expected needs. On a sharp mountain slope north of Machu Picchu, the source was fed by a tributary river basin of 16.3 ha, which in turn was supplied by drainage from a much larger hidrogeological basin (Wright, in Brown, 2001). The thousand inhabitants of Machu Picchu not only had access to water but also to an effective rainwater drainage system (Wright et al., 1999).

2. Water Sources and Accessibility

Although Peru is one of the richest countries in water resources, possessing 4.6% of the world's surface water, with water availability of 64,376.54 m³/capita/year, it has severe problems concerning

the territorial, Table 1 indicates that the Pacific side represents 21.6% of the country, comprises 62.5% of the population and contains just 1.76% of the country's water resources, while the eastern slope (Amazonas) represents 74.5% of the territory, is home to 33.3% of the population and possesses 97.9% of the water resources. This translates into extremely unequal water availability per capita between the Pacific slope (1000 851 m³/inhab/year) and the Amazon (189,167 m³/inhab/year).

The country is characterized by explosive urban growth in areas with lower water availability. Since this process has occurred with very little involvement on the part of the authorities, it has been largely spontaneous and informal. The proportion of the populations of Latin American capitals living in informal dwellings was approximately 50% in 2000, and is estimated at 40% in Lima (Clichevsky in Dureau et al. 2006: 245, cited by Durand, 2010: 11).

The largest urban centers are shown in Figure 3. At present, 46 cities have over 50,000 inhabitants while 14 have over 200,000. Eight of them are located on the Pacific slope (Piura, Chiclayo, Trujillo, Chiclayo, Lima, Ica, Arequipa and Tacna), one on the Titicaca slope (Juliaca) and five in the Amazon watershed, three of which are located in the sierra (Cajamarca, Huancayo and Cusco) and two in the rainforest (Iquitos and Pucallpa) (INEI, 2014).

Table 1. Distribution of Water Resources in Peru

Hydrographic Region	Area		Population		Water resources		Ratios	
	103km ²	%	Inhabitants	%	Hm ³ /year	%	Hm ³ /year	M ³ /Inhab/year
Pacific	278.48	21.67	18,801,417	62.53	34,136	1.76	0.12	1,815.61
Amazon	957.82	74.53	10,018,789	33.32	1,895,226	97.91	1.98	189,167.18
Titicaca	48.91	3.81	1,246,975	4.15	6,259	0.32	0.13	5,019.35
Total	1,285.21	100	30,067,181	100	1,935,621	100	1.51	64,376.54

Source: ANA, 2013: 28.

Table 2. Potable water and sewerage coverage and installation time for home connections by size of provider, 2012

Type of PA and S provider	Urban population served (2012)			
	Population Total	% Water coverage	% Sewage coverage	Hook up time in business days
SEDAPAL	9,256,885	94.59	89.86	15
Large	6,512,192	89.04	77.43	15
Medium	2,030,107	83.47	72.47	38
Small	805,669	80.81	66.20	18
Total	18,604,853	91.00	82.72	16

Source: SUNASS, 2012.

Lima-Callao, Peru's largest conurbation has approximately 11 times the population of Arequipa, the second largest city in Peru. The five most populous cities are located on the Pacific slope, while the largest city on the Amazonian slope is Iquitos, located near the Amazon River.

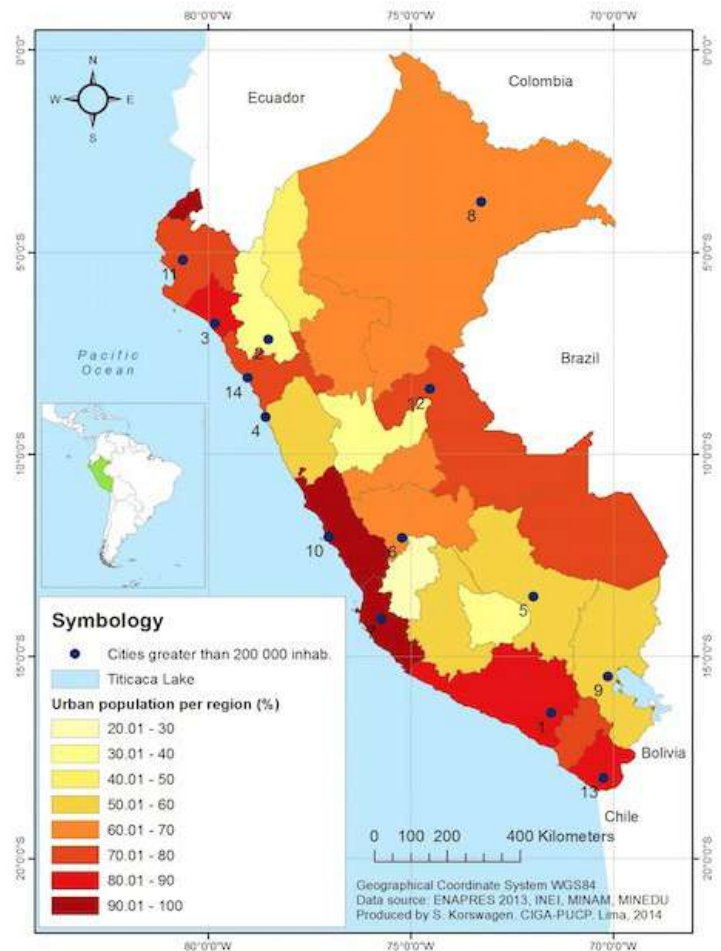
3. Drinking Water and Sanitation Services

3.1. Drinking Water and Sanitation Services in Urban Peru

Peru is one of the 189 countries that have signed the Millennium Development Goals. Meeting these goals has become state policy. One of the Peruvian government's most important programs was the "Water for All" Program, presented in 2006. During the official launch of the program, historical drinking water coverage and that projected for 2015 were indicated, according to the World Bank Water and Sanitation Service (Figure 4).

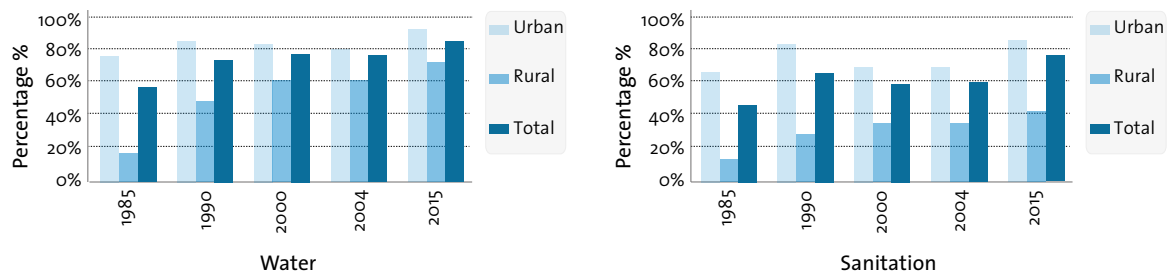
The National Sanitation Services Superintendence (SUNASS) (2012) analyzed the drinking water and sanitation provided by small, medium and large drinking water and sanitation Services Provider Companies (EPS). The Lima Potable Water and Sewerage Service Company (SEDAPAL), which provides water and sanitation services for the metropolitan areas of Lima and Callao, is a special case. An EPS is regarded as small when it serves fewer than 15,000 households. Medium EPSs provide services to between 15,001 and 40,000 households. Large EPSs serve over

Figure 3. Distribution of the urban population in Peru



Urban population: 1. Arequipa, 862,807; 2. Cajamarca, 211,608; 3. Chiclayo, 588,995; 4. Chimbote, 364,599; 5. Cusco, 413,006; 6. Huancayo, 357,279; 7. Ica, 293,363; 8. Iquitos, 427,367; 9. Juliaca, 260,607; 10. Lima y Callao, 9,585,636; 11. Piura, 424,124; 12. Pucallpa, 211,611; 13. Tacna, 284,244 and 14. Trujillo, 776,873.

Figure 4. Evolution of drinking water and sanitation coverage

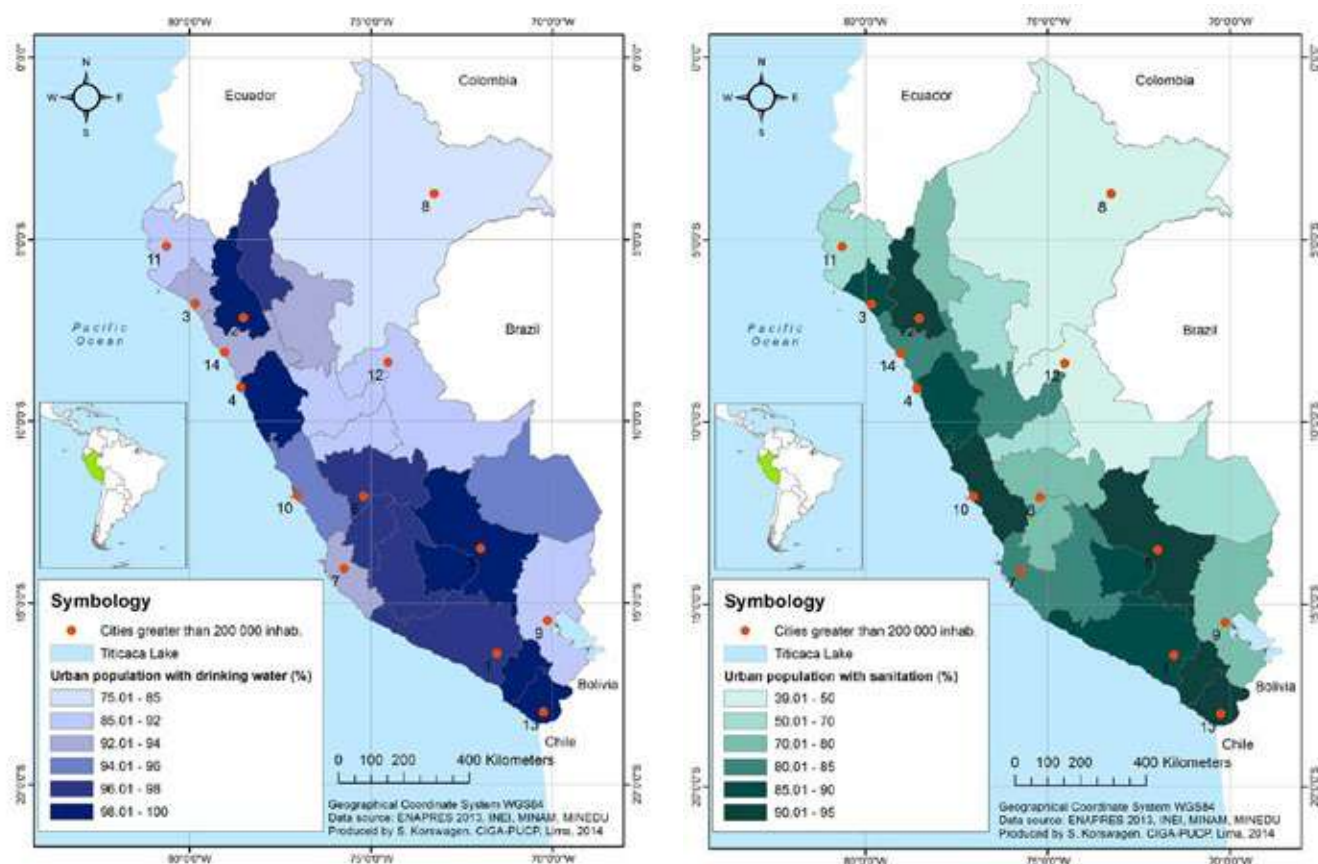


Source: For 1985: MVC 1986; for 1990: WHO and UNPF 2000; for 2000: MVCs 2000; for 2004: MVCs 2004, for 2015: WSP 2005, in Marmanillo, 2006.

Table 3. Volume of wastewater produced and processed by size of potable water and sewerage provider

DW and S Provider	Total Volume (MMC)	Treated volume (m ³)	Percentage (%)
SEDAPAL	428.48	88.48	20.6
Large	252.83	145.27	57.5
Medium	82.56	18.84	22.8
Small	34.68	8.33	24.0
Total	798.54	260.92	32.7

Source: SUNASS, 2012.

Figures 5 and 6. Urban population served with potable water and sanitation at the department level

40,000 homes. By late 2012, EPSs had achieved 91% potable water coverage and 83% sewerage coverage (Table 2). Continuity of service stood at 18.43 hours/day. The information provided in Tables 2 and 3 is based on data collected by SUNASS in 2011 (2012).

The total volumes and percentages of treated and untreated wastewater are shown in Table 3.

A large amount of sewage is not treated. In most cases, water is discharged directly into water courses and bodies, polluting the environment (Table 4).

The percentage of water supply and sewerage coverage by the EPSs responsible for these services is given below for the main cities in Peru (Table 5). In late 2012, wastewater treatment nationwide stood at 32%, showing very little variation from previous years. This situation changed in April 2013, due to the coming into operation of the Taboada wastewater treatment plant (SEDAPAL), which has increased sewage treatment in Lima from 21% to approximately 60%.

As regards micrometering and unbilled water, both indicators have shown improvements: micrometering has increased to 63% while unbilled water was reduced to 37%. Table 6 shows the percentage of micrometering and unbilled water according to the EPSs responsible in the country's major metropolitan areas.

It should be noted that although the Lima-Callao conurbation is the most highly populated region of Peru, only 13.3% of wastewater was treated in 2007 and 21% in 2010. The coming into operation of the Taboada wastewater treatment plant (SEDAPAL) increased wastewater treatment to approximately 60% (SUNASS, 2013:6). Untreated water is discharged into the Pacific Ocean and the Rímac and Chillón Rivers, polluting oceanic and inland water resources and riparian zones.

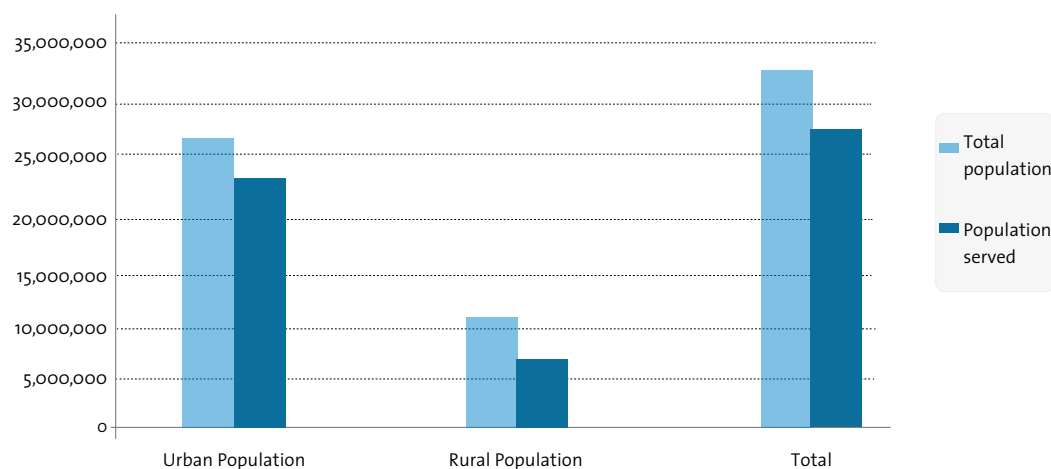
Despite these efforts focusing on Lima, it must be recognized that one of the main shortcomings of health services in Peru is the lack of treatment for most wastewater. Wastewater treatment methods are extremely varied in Peru due to the wide range of climates and geographical conditions. SUNASS

(2008) has pointed out that potable water and sewerage treatment plants are not properly operated or given adequate maintenance. Very few projects can be considered successful. The main causes of the deficit in wastewater treatment and inefficient treatment plants are given below: (i) Insufficient research and technological development, (ii) Lack of coordination between institutions in the area of sanitation, (iii) Insufficient resources for the operation and maintenance of water treatment plants, and (iv) Lack of financing for wastewater treatment.

It was estimated that by 2007, total investment for achieving the MDGs by 2015 would be \$4.042 billion USD. Annual investment would stand at approximately \$550 million USD.

Figures 5 and 6 show water supply and sewerage coverage in Peru. Water coverage is higher in coastal cities, where a large sector of the population is concentrated. The Lima-Callao Metropolitan Region has the highest coverage. In general, the lowest water coverage occurs in parts of the Sierra and the rainforest.

Figure 7. Urban-rural inequality in access to water, 2013



Source: Ministry of Housing, Construction and Sanitation, 2014.

Table 4. Volumes of wastewater: treated, untreated and total

Sewage produced by sanitation services	Volume per year (MMC/year)	Equivalent flow (m ³ /s)	% of treatment
With treatment	217.25	6.89	29.10
Without treatment	530.03	16.81	70.90
Total	747.28	23.70	100.00

Source: SUNASS, 2012.

Table 5. Potable water and sewerage coverage in major cities served by EPSs, 2013

Geographical Regions	CITY	EPS	Total urban population	Drinking water coverage (%)	Sewerage coverage (%)
COAST	Chiclayo and others	EPSEL S.A.	866,509	89.4%	80.8%
	Piura and others	EPS GRAU S.A.	1,049,547	89.3%	75.1%
	Trujillo and others	SEDALIB S.A.	943,942	85.3%	79.9%
	Tumbes	AGUAS DE TUMBES S.A.	202,250	80.2%	51.2%
	Chimbote and others	SEDACHIMBOTE S.A.	399,469	99.0%	96.4%
	Metropolitan Lima and Callao	SEDAPAL S.A.	9,354,380	96.3%	91.5%
	Ica and others	EMAPICA S.A.	204,496	91.0%	83.3%
	Tacna and others	EPS TACNA S.A.	271,448	97.1%	95.4%
SIERRA	Huancayo and others	SEDAM HUANCAYO S.A.	368,683	78.8%	72.6%
	Huánuco	SEDA HUANUCO S.A.	232,335	82.9%	77.5%
	Arequipa and others	SEDAPAR S.A.	1,046,867	93.4%	81.2%
	Cusco and others	SEDACUSCO S.A.	393,325	98.2%	96.0%
	Huamanga and others	EPSASA	224,340	93.4%	82.3%
	Juliaca	SEDAJULIACA S.A.	250,188	82.0%	83.2%
RAINFOREST	Iquitos	EPS SEDALORETO S.A.	476,041	93.0%	53.9%
	Pucallpa	EMAPACOP S.A.	221,805	61.3%	62.3%

Source: Compiled by the Ministry of Housing, Construction and Sanitation for this publication; regrouped by region by the author.

Table 6. Number of connections, wastewater treatment, micrometering and unbilled water in metropolitan areas, 2007

Metropolitan Area	Number of Connections	% of Wastewater treated	% of Micro-Metering	% of Unbilled Water	Services Provider Company (EPS)
Lima-Callao	1,194,879	13.3	70.1	37.5	SEDAPAL S.A.
Arequipa	201,144	16.1	64.2	35.9	SEDAPAR S.A.
Trujillo	135,883	80.1	37.7	45.7	SEDALIB
Chiclayo	133,767	89.2	9.3	41.6	EPSEL
Piura	163,824	50.6	19.9	55.9	EPS Grau
Iquitos	56,684	0.0	23.7	57.9	SEDALORETO S.A.
Cusco	57,497	75.4	78.2	46.0	SEDACUSCO S.A.

Source: SUNASS, 2013.

Table 7. Price of potable water and sewage service per m³ to 2011

Type of PW and S supplier	Price per m ³ (S./m ³)	Price per m ³ (US\$ /m ³)
SEDAPAL	2.41	0.87
Large	1.66	0.6
Medium	1.24	0.45
Small	1.03	0.37
Total	2.01	0.73

Source: SUNASS, 2011.

Table 8. Population growth in RML and Peru

Year	Lima		Peru	
	Population (in thousands)	Annual Growth Rate (%)	Population (in thousands)	Annual Growth Rate (%)
1940	645	-	6,208	-
1961	1,845	5.1	9,907	2.3
1972	3,303	5.4	13,538	2.9
1981	4,608	3.8	17,005	2.6
1993	6,345	2.7	22,048	2.2
2007	8,482	2.1	27,412	1.6

Source: INEI, 2007.

Large inequalities in coverage between regions can be observed, together with significant gaps between rural and urban populations, as shown in Figure 7.

Water rates

The price per cubic meter of drinking water is given in Table 7, which shows the price of SEDAPAL and drinking water and sanitation providers in local currency and US dollars in 2011. An exchange rate of 2,76 soles to the dollar was used. In general, prices were kept low because wastewater treatment coverage remained low until 2011. Prices are higher in the Lima-Callao Metropolitan Region because water treatment is expensive due to the high burden of pollutants in the Rímac River.

Maintaining rates that do not include sustainability criteria constitutes a perverse incentive for users, as they will tend to use more water because of its low cost. Furthermore, the absence of rates that increase exponentially once they exceed basic household consumption encourages families to use disproportionately more water than that required to cover basic needs (Peruvian Society of Urban Planners, 2011).

3.2 Water and Sanitation in the Lima-Callao Metropolitan Region

The Lima-Callao Metropolitan Region (RMLC) comprises the Lima Metropolitan Region (RML) and the Callao Region (RC). The Lima Metropolitan Region comprises 43 mainly urban districts, with a total population of 8,48 million in 2012 (INEI, 2012). The RC, located in the west of Lima and adjacent to the Pacific Ocean, comprises six districts with a total population of 0.97 million. These two regions together contain 9.45 million inhabitants. The birth rate has significantly declined, with urban women having an average of two children. However, migration

to the cities remains high, which greatly increases the growth rate of urban areas. Table 8 shows and compares the growth of RML and Peru between 1940 and 2007.

Three rivers cross the RMLC. From North to South, these are the Chillón, the Rímac and the Lurín (Figure 8). The main features of the three basins, together with the total area of the basin, the main channel length, maximum and minimum altitudes, average slope and discharges are presented in Table 9.

These three basins constitute the main water sources for the RMLC for surface and groundwater extraction, as well as the collection of fog water in certain poor urban neighborhoods. Seawater is not used.

The Rímac River is the main freshwater source for the RMLC. Water is taken from Rio Chillón at a rate of 2 m³/s during the rainy season and 1 m³/s in

Figure 8. Chillón, Rímac and Lurín rivers and RMLC



Source: Metropolitan Municipality of Lima, 2001.

Table 9. Main characteristics of rivers flowing through the RMLC

Cuenca	Area (km ²)	Length (km)	Maximum Altitude (masl)	Minimum Altitude (masl)	Average slope (%)	Average flow (m ³ /s)
Chillón	2,353	126	4,850	0	3.85	8.74
Rímac	3,504	127	5,100	0	4.02	29.00
Lurín	1,670	109	5,300	0	4.86	4.27

Source: ANA, 2013.

the dry season. Water is not extracted from the Lurín River for Lima's drinking water service. Most of the water is used for agriculture purposes.

To complement the volume of water needed to cover the RMLC's demand, water is transferred from the Upper Mantaro River to the Pacific slope. The Marcapomacocha project involves storing water in existing lagoons on the Amazonian slope. Closure dams have been built in these lagoons to increase their storage capacity. Water is stored in lagoons during the rainy season. A system of canals carries water to the dammed lagoons and then to the Pacific slope through the Transandean Tunnel, carrying water to the upper basin of the Rímac or Chillón rivers.

Groundwater extraction totaled approximately 3.6 m³/s in the RMLC in 2011 (INEI, 2012). The extraction rate has significantly decreased due to the closure of wells caused by the pollution of groundwater resources. Filtration galleries are no longer used in Lima. The evolution of groundwater extraction in Lima in MMC per year and the equivalent discharge are presented below in Table 10. Together with 452 SEDAPAL wells, 284 of which are operational, there are over 1,100 wells operated by the state, industrial and agricultural sectors and countless informal wells (SEDAPAL, 2012).

Lima produces an annual average of 544 million m³ of wastewater, i.e. approximately 17 m³/s with

peaks of 24 m³/s (SEDAPAL, 2005 Vol.2: 49; DIGESA, 2008: 5), equivalent to an average of 170 liters (0.17 m³) per person/day. Drinking water production is 23.1 m³/s, in other words, over 730 million m³ annually (SEDAPAL, 2009: 15). Of this amount, 692 million m³ are produced by SEDAPAL, and 38 million m³ by alternative supply systems (wells, tanker trucks and so on). Average drinking water consumption per person per day is between 229 and 250 l., whereas in many European capitals it fluctuates between 150 and 190 l. (SEDAPAL, 2009: 4). This high water consumption means high wastewater production.

SEDAPAL studies indicate the gaps between the water consumption of wealthy social groups (between 330 and 460 l./Inhab./Day) and poor groups (between 103 and 145 l./Inhab./Day). Populations living in extreme poverty are not listed in the classification since they lack access to water. Consumption is usually less than 30 l./inhab./day (Figure 9).

The evolution of the index of access to networks (Figure 10) shows that during the first phase (1981), the city center had been connected to the sewerage network (over 75%) for a long time, whereas low income neighborhoods had a rate of access of under 75%, of 50% at most.

The following phase (1993), described in the 1993 census, shows that the first peripheries are undergoing a process of consolidation. Finally,

Table 10. Extraction of groundwater in the RMLC, 2000- 2011

Year	Production (MMC)	Average flow (m ³ /s)
2000	190.32	6.02
2001	176.61	5.58
2002	163.62	5.17
2003	127.37	4.03
2004	174.48	5.52
2005	151.34	4.79
2006	139.33	4.41
2007	105.56	3.34
2008	133.36	4.22
2009	108.44	3.43
2010	118.37	3.74
2011	115.80	3.66

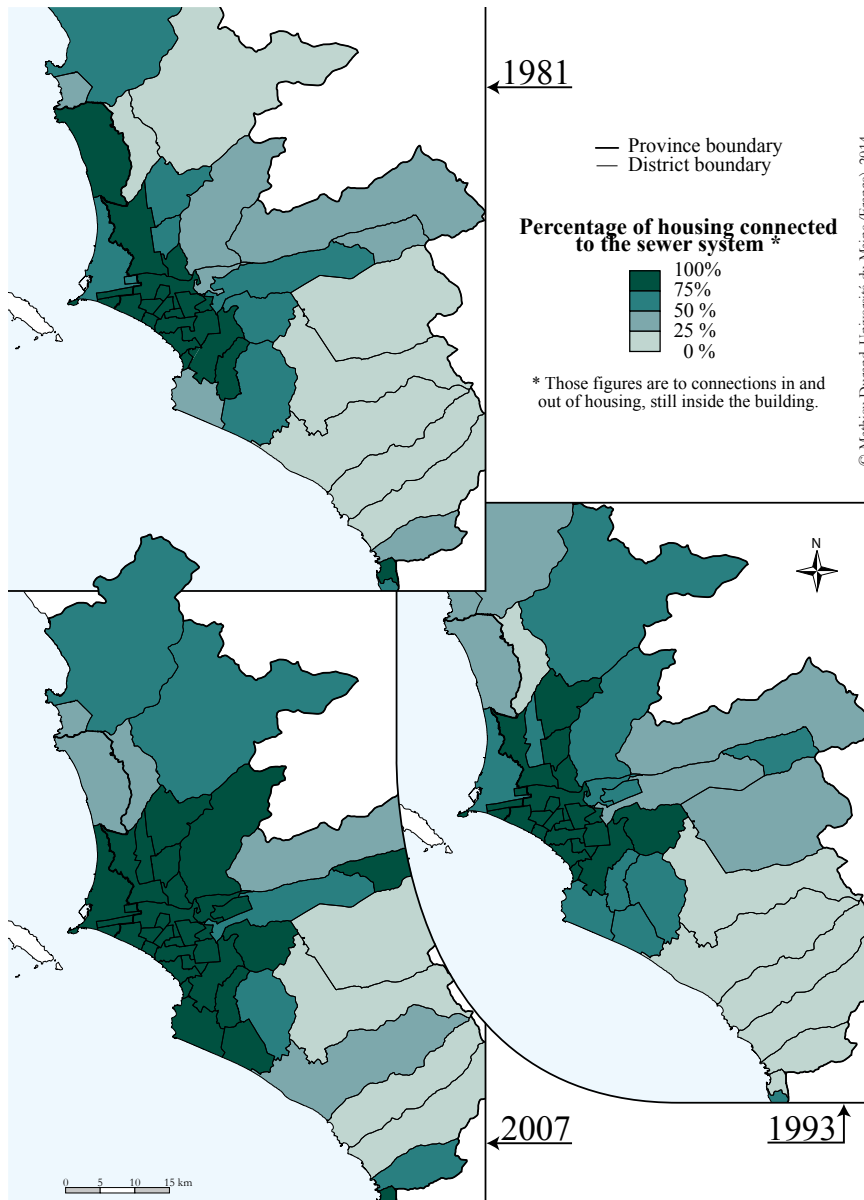
Source: SEDAPAL, 2005, 2009 and 2012.

Figure 9. Channel discharging wastewater in areas not connected to the sewerage networks, Huachipa 2009



Photo: Mathieu Durand.

Figure 10. Figure 10. Rates of access to sanitation in RMLC in 1981, 1993 and 2007



Source: Durand, M., 2010.

during the last phase (past 12 years), large peripheries have gradually been incorporated, in other words, districts with informal urbanization, while the oldest suburbs such as El Callao, El Agustino and Chorrillos have continued to be consolidated.

The Lima Potable Water and Sewerage Service (SEDAPAL) is the company that provides potable water, sewerage and wastewater treatment services in the RMLC. This company belongs to the Ministry

of Housing, Construction and Sanitation, which reports directly to the Central Government.

The La Atarjea water treatment plant is located on the left bank of the Rímac River. This plant began operating in 1956 with an initial capacity of 5 m³/s. It was the treatment plant with the greatest capacity in the world at the time of completion of its construction (SEDAPAL, 2013). In 2010, SEDAPAL channeled between 15 and 19 m³/s to the La Atarjea

Plant to supply water to Lima. During the dry season (May to November), the average annual flow is about 23.5 m³/s. It has been estimated that the ecological flow is 1.5 m³/s (Yepes, 2002). The La Atarjea water plant processes approximately 20 m³/s and captures virtually all the flow available during the dry season. Water availability in the Rimac River basin is approximately 148.6 m³/inhab./year whereas in the Rio Chillón it was approximately 202.2 m³/inhab./year in 2005, well below the threshold of 1000 m³/hab./year defining the state of water scarcity (Salazar, 2005). In 1876, stone masonry and concrete dams were built for energy and agricultural purposes and from the mid-20th century onwards to improve the drinking water supply in Greater Lima. In addition to Marca I, Marca II was expanded (through the construction of a 10 km tunnel, the expansion of the capacity of the Lower Huallacocha and Pomacocha dams), Marca III was built for storage and reserves (Santa Eulalia Lagoons, Yuracmayo and Antacoto dams), while Marca IV (Huascacocha-Rimac) was constructed to allow an average additional flow of 2.5 to 3 m³/s.

In 2011, construction was completed of the new water treatment plant, Huachipa, upstream of the La Atarjea plant. This allows water to be transported by gravity to sectors that could not be supplied in the same way from La Atarjea. Total water treatment capacity is 10 m³/s, although at present, it only captures 5 m³/s. It is expected to operate at full capacity when the Marcapomacocha projects are completed. SEDAPAL has invested approximately

\$461 million USD in the project, which will provide potable water and sewerage services for 2.5 million inhabitants in the northern sector of the RMLC.

Consortio Aqua Azul S.A., a private partnership between Peruvian and foreign investors, won a concession under the Build, Operate and Transfer (BOT) model to build a water treatment plant that will take approximately 2 m³/s of water from the Chillón River during the wet season and 1 m³/s during the dry season. This river is heavily polluted.

The Rímac River is one of the most highly polluted waterways in Peru. The sections are classified as Type II or Type III. The maximum permissible limits according to both Peru and the World Health Organization (WHO) are exceeded in several areas of the river. The basin contains old tailings dams, mines and processing plants that have contributed to the pollution from heavy metals, particularly arsenic, cadmium, copper and zinc (Méndez, 2005). The basin has also been polluted by domestic sewage, since there are several towns and small cities that discharge effluents into the river without any form of treatment. In the middle basin, towns and cities such as Surco (1,798 inhabitants), Matucana (4,508 inhab.) and Chosica (169,359 inhab.) discharge untreated sewage into the Rímac river. The district of Santa Eulalia, with a population of 10,591 inhabitants, discharges untreated sewage into the river of the same name, a tributary of the Rímac. Agricultural activities also contribute to pollution since fertilizers and pesticides are washed into the river when the land in this watershed is irrigated.

Table 11. Parameters measured at the intake of the La Atarjea Plant and reservoirs

Physico-Chemical Parameters	Rimac River			Water in Reservoir	General Water Act		
	Maximum (mg/l)	Minimum (mg/l)	Average (mg/l)		Class II (mg/l)	Class III (mg/l)	WHO drinking water quality standards (mg/l)
Iron Fe+3	50.600	0.269	6.991	0.199	0.300	1.000	-
Manganese Mn+2	1.143	0.023	0.207	0.055	0.100	0.200	0.400
Lead Pb+2	0.379	0.009	0.089	0.016	0.050	0.100	0.010
Cadmium Cd+3	0.010	0.001	0.004	0.003	0.010	0.050	0.003
Aluminum Al+3	2.256	0.160	3.695	0.112	-	-	0.100
Arsenic As+3	1.101	0.035	0.392	0.048	0.100	0.200	0.010

Source: SEDAPAL, 2005.

Heavy metals, fecal coliform and other pollutants have been detected throughout the middle and lower sections of the river.

Table 11 shows the heavy metal concentrations in the La Atarjea intake. Maximum heavy metal concentrations exceed the maximums permissible for classes II and III of the watercourses in the General Water Act (D.L. N°17752).

The class II and III parameters can be compared with those of the WHO. The parameters were measured in 2002.

The illegal occupation of land exacerbates the problems of water supply and sanitation. The city of Lima has seen illegal land occupations since the 1950s. In the beginning, squatters occupied the hills surrounding Lima as shown in Figure 11. Years later, they began to occupy the periphery of the city, taking over agricultural fields and fallow land. There are legal problems due to the fact that if property is not registered in the public records, it is not possible to sign contracts with the occupants. In some cases, it is difficult and costly to deliver water to the marginalized human settlements located in the hills because it is necessary to pump water uphill. In addition to the high initial outlay, operating and maintenance costs are exorbitant. Approximately 984,727 inhabitants lacked access to safe drinking water in 2011.

The population of Lima is expected to continue to grow at a high rate due to migration within the country. Water availability per capita is therefore expected to continue to decline.

Freshwater resources are being depleted, meaning that new sources will be required to meet future demands. Transferring water from other basins and desalinating seawater have been considered, among other alternatives.

Problems have also been identified with the water distribution system. Unbilled water accounts for approximately 37.5% of that produced by SEDAPAL. Roughly 29.9% of the households that receive this service do not have meters. Additional measures must also be taken in order to be able to record and identify losses in the system and optimize the water supply processes required.

Numerous environmental and geomorphological changes are caused by anthropogenic activities in the urban section of the Rimac River. Martínez and Martínez (2004) and Kuroiwa et al. (2011) iden-

tify the causes that led to the formation of an urban canyon in Lima (Figure 12). The bed of the Rimac River was deepened approximately 20 m downstream of Puente del Ejército, built in 1936. The installation of a prefabricated metal bridge led to the narrowing of the channel. This caused the incision of the channel by increasing the stresses on the river bottom. Former floodplains were illegally occupied by people who live under the constant threat of landslides. Kuroiwa and Valle (2014) note that the formation of the urban canyon caused the disappearance of the *Chryphios caementarius* river shrimp (Molina, 1872). Several structures located downstream from Puente del Ejército, such as the Dueñas Bridge, were affected. Kuroiwa et al. (2004) describe a temporary solution that helped stabilize Puente Dueñas. However, this temporary solution has become permanent since erosion control has been satisfactorily achieved since the summer of 2002, and no definitive solutions have been proposed by the Metropolitan Municipality of Lima (MML).

Supplying the city of Lima and Callao, with more than 1.1 million water connections and an equal number of sewerage connections, forces SEDAPAL - a state monopoly water management company- to address numerous problems highlighted in Table 12, and solve them, while recovering its exploitation costs (operational), repositioning capital and expanding service (investment). A number of problems have yet to be addressed, such as the renovation of networks, better sewage treatment, enormous losses due to unbilled water (34.58% until 2011) and water loss from leaks in extremely old networks (Prialé, 2012).

In 2011-2012, the variety of problems led to a review of the management of the company and the implementation of a major investment program in the expansion, optimization of water and sewerage services, and the rehabilitation and improvement of networks (from 2013-2016) through 148 projects totaling 8,443,500 soles and benefiting 1.9 million residents. These projects were known as Expanding Coverage to 100% (Figure 13), Rehabilitation (Figure 14) and Diversification of Sources (Figure 15). As for the Projects to Expand Coverage to 100%, the challenge is to achieve universal access through 81 projects involving a total investment of S/. 5,631,732.00.

The 67 Rehabilitation Projects involve a total investment of S/. 2,812,000.

Finally, projects to diversify sources must ensure the supply of the country's largest metropolitan population, through the treatment and reuse of its water (Figure 15).

3.3 Water and Sanitation in the City of Cusco

Cusco is the capital of the Cusco Region and the former political center of the Inca Empire and the region where Peru's main attractions are located. The city of Cusco is located at an altitude of 3,399 masl. The current population is estimated at approximately 410,000 inhabitants. Studies of the Middle River and lower Huatanay indicate that 100% of the water supply for the populations of the South Valley of Cusco comes from groundwater, meaning that it is the only source of water, and requires artificial recharge to maintain and improve the production levels of springs. Likewise, although 98.19% of the population of South Valley have a water supply system, only 17.01% of the total have potable water, 82.99% have piped water and 1.81% no service, meaning that the Ministry of Health (MOH) should exert greater control over water quality in the supply systems. As regards the system of sewage

disposal and sewerage, in the districts of San Jerónimo, Saylla, Oropesa and Lucre, this is directly administered by the district municipalities, and both the service and maintenance of the networks is poor (Bernex, 2005).

As pointed out by Bernex et al. (2005), the quality of the water in the Huatanay River has considerably declined in recent years, since it contains an increasingly large load of contaminants, making the water unfit for any use. The first sign of this condition is its dark color and the odor it gives off, particularly in the afternoon. Mendiivil Riveros et al. (2002) states that the main problems of the Huatanay River were flooding due to narrowing of the channel at various points in the city and pollution caused by the dumping of untreated sewage, reflected in the high number of fecal coliforms, and refuse thrown into the river (Figure 16).

Cusco's main supply source is the Huatanay River Basin, which is highly polluted due to the direct discharge of industrial and domestic sewage. In the middle and lower basin of the Huatanay River, water quality is poor, meaning that it must not be used for any purpose (CEC Guaman Poma de Ayala, 2004).

Figure 11. Water supply in a rural area on the outskirts of Lima (La Atarjea, 2012)



Photo: Julio Kuroiwa, 2013.

Figure 12. Urban Canyon formed by the degradation of the Rímac Riverbed downstream of Puente del Ejército



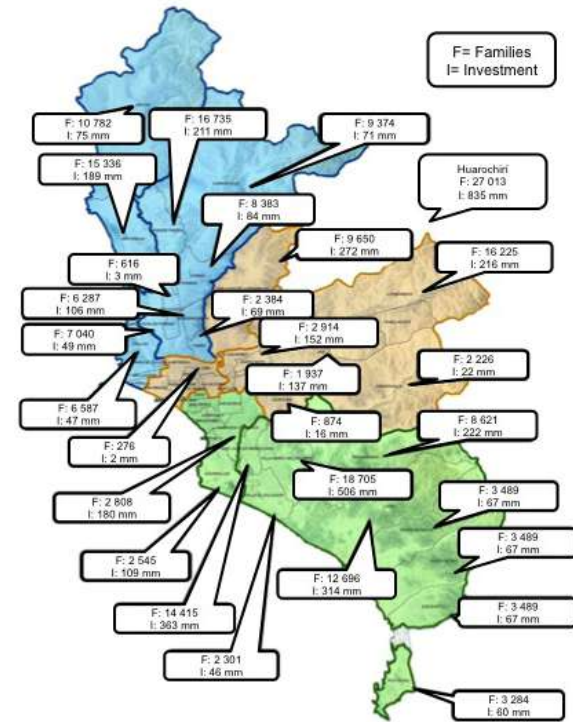
Source: Luis Castro Inga, 2010.

The company responsible for the water supply in the city of Cusco is SEDACUSCO, SA, whose board comprises the metropolitan mayor of the city of Cusco and district mayors. In February 2014, with a total investment of S/102 million, a modern Wastewater Treatment Plant (WWTP) was inaugurated to treat 80% of the waste produced by the Imperial City and the province of Cusco, benefiting 330,000 users. This plant will ensure the clean irrigation of vegetables and other crops. It was built using latest generation technology and includes a system for the total elimination of odors.

3.4 Potable Water and Sanitation in the City of Iquitos

Iquitos, the Capital of the Peruvian Amazon, is located on the left bank of the Itaya River, a tributary of the Amazon River, at an altitude of 106 masl. It is a tropical area with an annual average rainfall of

Figure 13. Projects to expand coverage to 100%



Source: Ismodes, 2013.

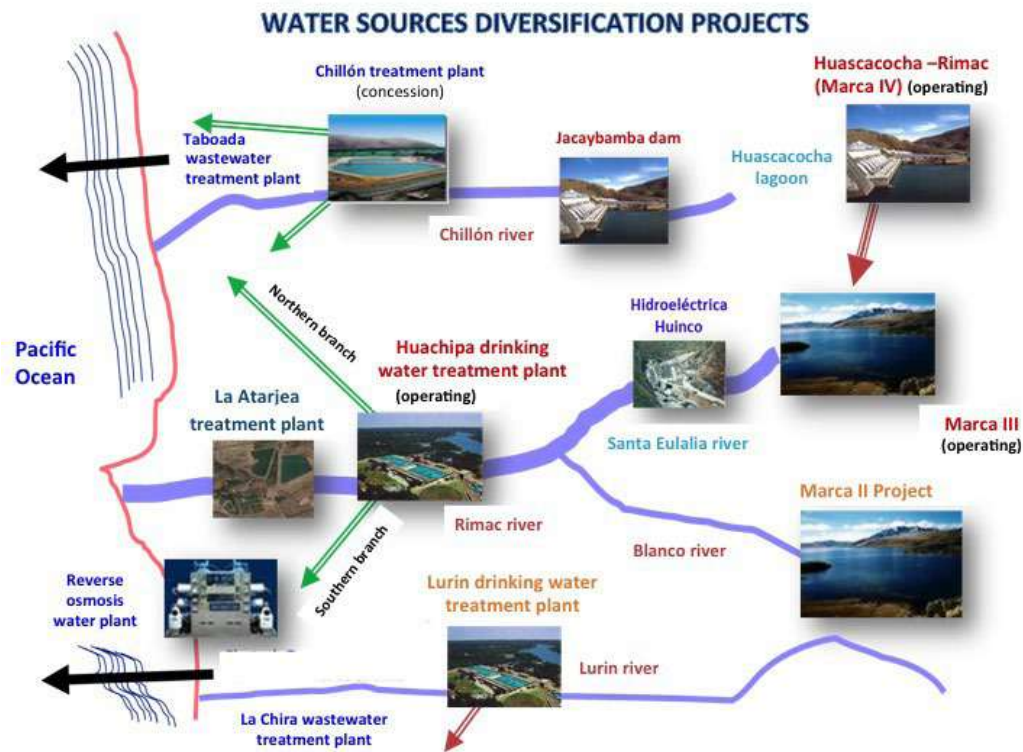
more than 2000 mm/year. Water for human consumption is captured in the Nanay River, a tributary of the Amazon River.

The local EPS is Sedaloretto, SA, which belongs to the municipality of Iquitos. Its functions include the acquisition, production and distribution of drinking water; sewage collection and disposal; and sanitary excreta disposal.

The district of Belén is located on the left bank of the Itaya River. Two-storey wooden houses have been built on wooden stilts above maximum flood levels. During the rainy season, the inhabitants of these houses only occupy the top level.

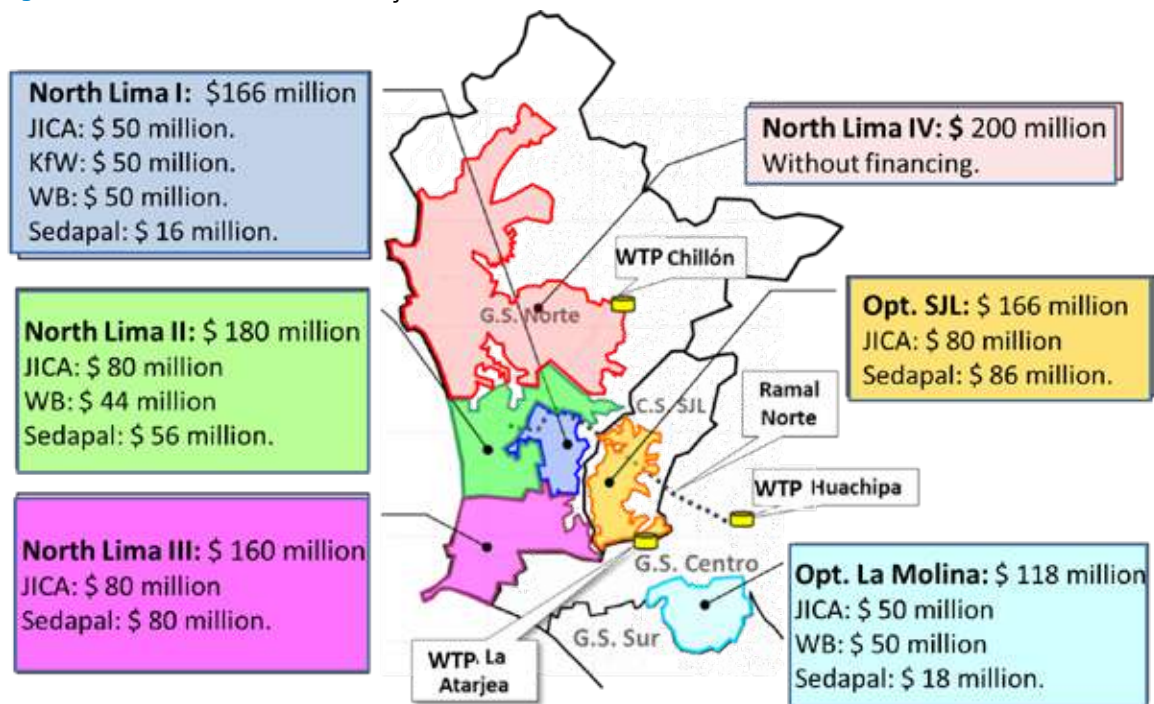
However, sewage disposal is complicated by the restrictions of the location. Domestic sewage is discharged untreated from every home into the Itaya River, which contaminates this important waterway (Figure 17). The sanitation deficit for a population of 41,000 inhabitants occupying 7,827 households was 73.8% in urban areas in 2007 (INEI, 2010).

Figure 14. Rehabilitation Projects



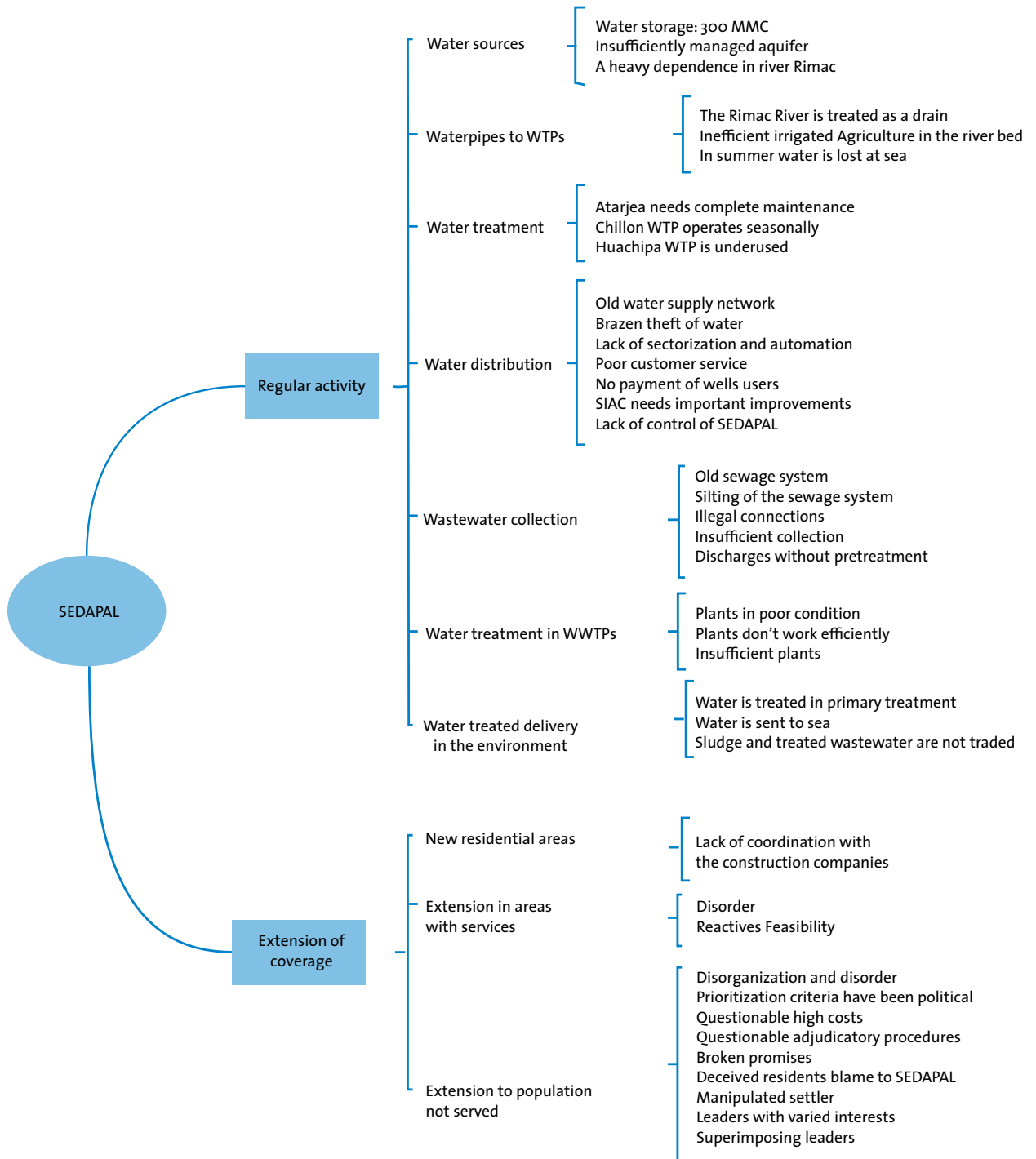
Source: Ismodes, 2013.

Figure 15. Diversification of Sources Project



Source: Ismodes, 2013.

Table 12. Major problems in SEDAPAL, 2013



Source: Ismodes, 2013.

The Japanese International Cooperation Agency (JICA) has helped improve sanitation services in Iquitos. In August 2010, work began on the “Expansion and Improvement of the Water System in the city of Iquitos” and “Improvement and Extension of the Sewerage System and Installation of Plant Wastewater Treatment for the City of Iquitos” projects. Expected investment totaled \$210 million USD with an estimated 50,000 beneficiaries. The goal was for 80% of the population of Iquitos to have access to water for 20 hours a day with average consumption of 180 l/inhab/day (JICA, 2010).

3.5 Water Treatment and Reuse

Current information on municipal wastewater production at the national level corresponds to the production of domestic or municipal wastewater, reported by the EPSs. The average annual volume of domestic wastewater at the national level (2009–2011) is 798,539,655 m³, of which only 260,916,866 m³ are treated. Figure 18 details current wastewater management levels in RMLC.

In 2010, 428 million cubic meters of wastewater, equivalent to 80.4% of the total, were discharged untreated. Contaminated water flowed directly into the Pacific Ocean through two collectors or into the Rímac River, which eventually carried the effluents into the ocean, contaminating the coastline. Two collectors were used to transport wastewater to the sea: Costanera (2.26 m³/s) and La Chira (8 m³/s). The Spanish company ACS Servicios, Comunicaciones y Energía recently completed construction of the Taboada Wastewater Treatment Plant, which is beginning to operate. The projected average capacity for this plant is about 14 m³/s (equivalent to 442 MCM/yr) with peak flows of 20.3 m³/s. This flow represents 72% of the total drainage flow. Moreover, construction of the La Chira Wastewater plant began in June 2013 (El Comercio, 2013). The projected average capacity of this plant is 6.3 m³/s with a peak capacity of 11.3 m³/s by the time construction is completed in January 2015. By early 2015, potable water, sewerage and wastewater treatment coverage is expected to reach 100% in RMLC.

Due to the low percentage of treated wastewater, the Ministry of Housing, Construction and Sanitation approved the “National Sanitation Plan 2006–2015,” which envisages that 100% coverage for

domestic effluents will be achieved by 2015. Moreover, Policy Guidelines are being implemented by a multisectoral committee to promote treatment for the re-use of domestic and municipal wastewater in the irrigation of urban and peri-urban green areas.

Despite this difficult situation, there have been success stories. Thus, in 1966, the Colegio de la Inmaculada, founded in 1878 and belonging to the Catholic religious congregation of the Society of Jesus, was forced to move, driven by the growth of Lima, to the south, to an arid, untitled area. In 1995, it was decided to develop the Ecological Project, which includes wastewater treatment with oxidation ponds to solve the problem of water for the irrigation of gardens and sports fields, and reduce maintenance costs for the 30 hectares of the school grounds.

Figure 16. Discharge of cuttings into the Huatanay (San Juan de Dios, San Jerónimo, Cusco)



Photo: Guamán Poma de Ayala Center, 2005.

Figure 17. Iquitos, sewers in the neighborhood of Belén



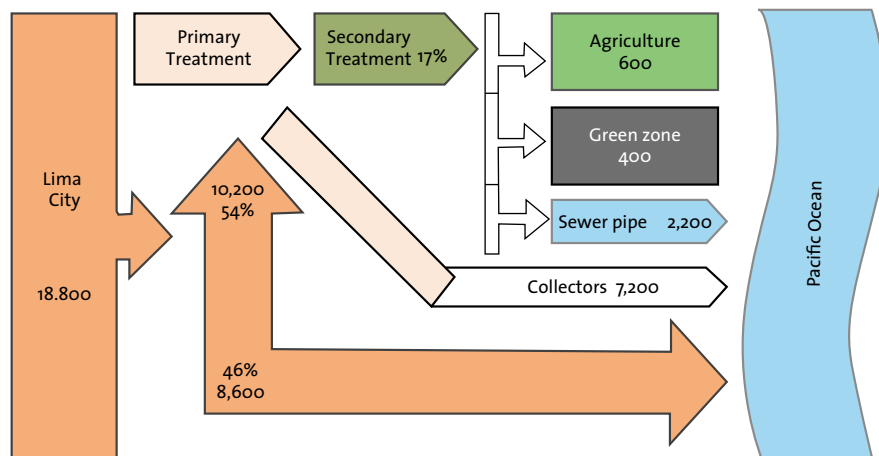
Photo: Nicole Bernex, 2013.

The mechanism by which this recycling system operates is simple yet effective: wastewater is collected in the early morning hours from the Santiago de Surco drain; passed through a grid system that filters it, capturing solid waste; and subsequently transferred to the oxidation ponds built on the slope of the hill adjacent to the school. When they reach the ponds, bacteria (fungi, protozoa) from the wastewater interact with millions of microalgae, which produces oxygen (oxidation), which, when it dissolved in the water, activates the bacteria, breaking up all the organic matter. This disintegration produces carbon dioxide and inorganic matter, elements required for microalgae to produce carbohydrates. The cycle is thus completed through a series of transformations,

where matter from the animal kingdom decomposes and enters the plant kingdom. This enables water of the required purity for use in the irrigation of the school's gardens and sports grounds to be released on a daily basis (Figures 19 and 20).

The main advantage is that students learn first-hand that it is possible to turn the desert into forest. In addition to saving the community potable water, the project helps reduce the amount of wastewater flowing into the sea. It also achieves significant monetary savings. As part of this project, there is also a zoo nursery, reforestation programs and worm farming complemented by solid waste management in the school and the sale of part of the agricultural production at a small vegetable store on the school grounds (cf. www.ci.edu.pe).

Figure 18. Current wastewater management in Metropolitan Lima (l/s)



Source: Julio Moscoso Cavallini, 2011.

Figures 19 and 20. Oxidation ponds and green areas irrigated with treated water from the Colegio de la Inmaculada, Lima



Photos: Fernando Roca, 2013.

4. Waterborne Diseases

The diseases caused by contaminated water not only affect public health, but are also associated with a loss of revenue due to lower productivity and absenteeism. Improvements in access to clean water and sanitation are cost effective. It is estimated that in developing regions, for every \$1 USD invested in water and sanitation, between \$5 and \$46 USD are earned. Drinking water and sanitation are also related to the right to education. Being unable to exercise the “right of access to drinking water” may prevent children from going to school and force women to travel great distances, often several times a day, to fetch water for their families. The main diseases caused by the ingestion of water contaminated with human/animal waste containing pathogenic microorganisms or water contaminated with chemicals” are infectious, toxic and indirectly related (Table 13).

The National Institute of Statistics and Informatics of Peru (INEI) (2009) found a link between lack of potable water and sewerage and infant mortality rates. The infant mortality rate is 15.2 per thousand births in cases where households

have water services provided by the public network, and 24.3 per thousand births when the source is different. Similar results were found when sewerage was analyzed. The mortality rate is 13.2 deaths per thousand births when the service is provided by the public network. Mortality increases to 24.3 per thousand births when there is no public network service (Table 14).

5. Water and Fire

Urban anthropogenic fires are common in all cities, particularly in Lima. They are caused mainly, “by faulty electrical installations, gas leaks, improper handling of flammable materials, lit candles and poorly maintained gas tank containers, among other factors.” (INDECI, 2013).

Figure 21 shows a significant increase in the number of urban fires recorded nationwide by the Peruvian National Institute of Civil Defense (INDECI) from 1995 to 2002. The upward trend started in 2000, 2005 being the year with the highest number, with

Table 13. Classification of waterborne diseases

Photos: Fernando Roca, 2013.	Description	Examples
Water-borne	Fecal contamination	Cholera, typhoid bacillus and , enteric pathogens
Water-based	Organisms that spend a portion of their life cycles in water	Paragonimosis and Fasciolosis
Water-related	Vectors that reproduce in water	Malaria, Dengue fever
Water-washed	Associated with poor personal hygiene and contact with polluted water	Scabies, rickets
Water-dispersed	Organisms that proliferate in water and enter via the respiratory tract	Legionella

Source: Cabezas, 2013.

Table 14. Relationship between infant mortality rate and type of service

Parameter	Women of childbearing age	Percentage (%)	Infant mortality rate (per thousand)
Water supply			
Public network	5,159,230	68.2	15.2
Other	2,405,554	31.8	24.3
Sewerage			
Public network	4,893,925	64.7	13.2
Other	2,671,859	35.3	24.3

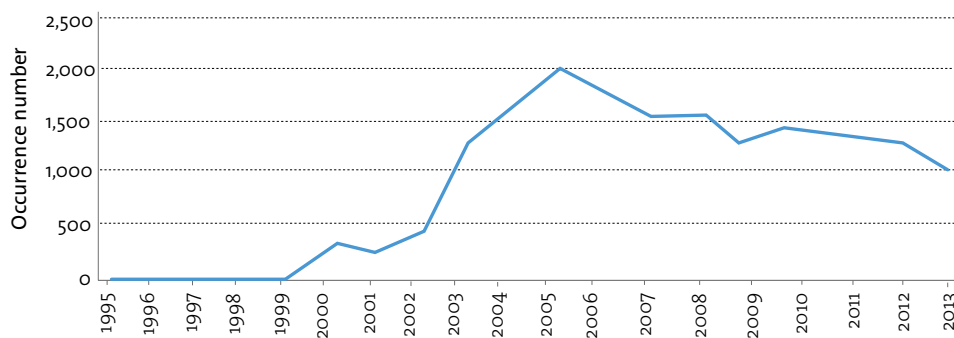
Source: INEI, 2009.

1,962 cases. The number of urban fires rose from 73 in 1995 to 1048 in 2013, an increase of 1,435%

A key factor in dealing with fires is the availability of water resources, which prevents fire from spreading to adjacent areas. To control everyday fires, firefighters face a number of difficulties, including the lack of hydrants, the distance from which they are located from the emergency area and in the event that hydrants exist, their inoperability (Espacio 360, 2013). In Lima and Callao there are 17,010 hydrants, not enough to cover emergencies around the Lima area. The city has spread, occupying areas regarded as unsuitable for habitation, such as hillsides. Major changes in land use have occurred; while markets, commercial, industrial and service areas have multiplied. All these areas are vulnerable

to accidents. It is important to recall the 29 people killed in a fire at the Utopia nightclub located in the elegant Jockey Plaza mall in 2001 and the 277 people killed and 180 missing in Mesa Redonda, an informal and precarious market in downtown Lima. In most cases, firemen's work is hampered by the lack of hydrants as well as difficulty of access due to overcrowding in the area. It is also important to underline the lack of operability of existing hydrants, whose maintenance should be ensured by SEDAPAL. The Peruvian General Voluntary Firemen's Corp of Peru files a report whenever it detects a hydrant in disrepair. Despite firefighters' continuous reports, the state agency "does not keep a detailed record of how many hydrants have been reported as faulty or in poor condition." (Espacio 360, 2013).

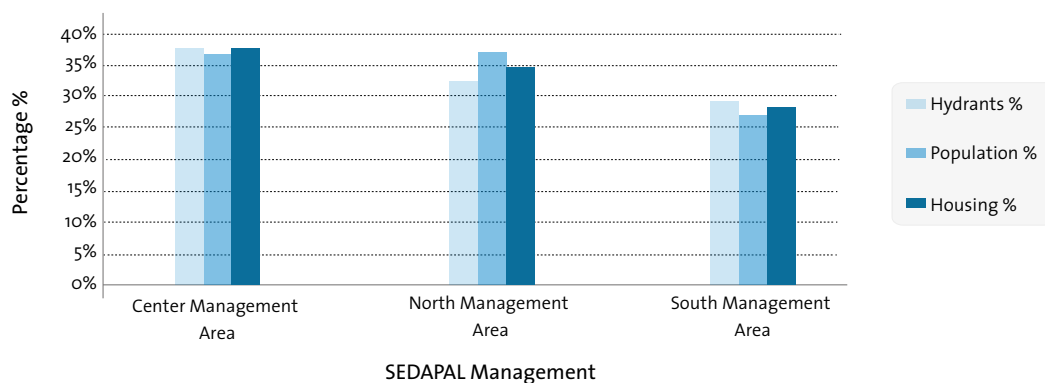
Figure 21. Time evolution in the occurrence of urban fires nationwide for the period from 1995 to 2013



*Preliminary figures

Sources: 1995–2002: INDECI, 2003, 265 pp.; 2003–2013: INDECI, Cuadros Estadísticos, Time series of national emergencies by phenomenon
<http://www.indeci.gob.pe/objetos/secciones/MTM=/NTM=/lista/NDco/201403041217091.pdf>

Figure 22. Comparison of percentages of hydrants, population and housing among the three SEDAPAL departments in Metropolitan Lima and Callao



Source: Compiled by the author.

In addition to technical problems, SEDAPAL and firefighters must address another problem related to hydrants, associated with social issues. Parts are stolen and sometimes misused. This is the most serious problem facing SEDAPAL, according to the company’s Research and Development manager Juan Carlos Barandiarán Rojas. For example, “In the Cercado de Lima area alone, between January and December of last year [2012], they found 13 hydrants that had been tampered with by criminals and water thieves.” This situation is repeated in districts such as Brena, Pueblo Libre, Magdalena, Ate and San Miguel (Correo 2013). This issue is more about responsibility and respect for firefighters’ work as well as education and awareness about what hydrants represent in fire control.

SEDAPAL attempts to meet these challenges and has therefore developed a mobile app for smartphone to reduce the time it takes for firemen’s units to find the faucet closest to where a fire is taking place. This tool enables to find firefighters to quickly locate hydrants within a 500-meter radius in real time. The two institutions now also have better communication , allowing them to be simultaneously aware of a state of emergency (El

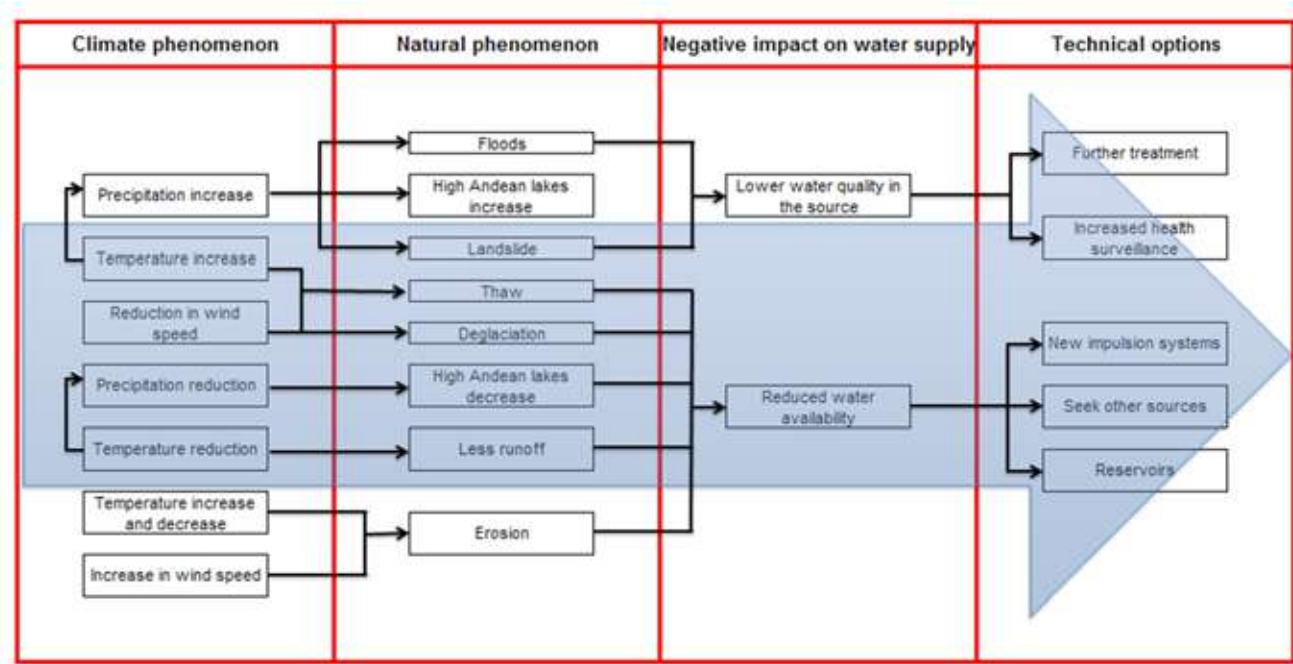
Comercio, 2013) and to instruct SEDAPAL to open the main pipes (Mail, 2013). There is a recurring problem of fires in houses built from rustic materials such as wood, mats, plastic and straw, which are highly flammable. It is also common for parents going off to work to leave their children alone in these dwellings, with the door locked. In the event of a fire, some manage to survive, albeit with wounds and burns while others die. Firefighters often have to deal with fires in precarious human settlements, some of which do not have access roads, hampering the entry of fire units. Nor are there any water distribution services, essential for fire fighting.

Figure 22 shows the comparative advantages of the three departments in RMLC. The Southern Region (the oldest, best consolidated part of Lima) undoubtedly has more hydrants in relation to the others.

6. Climate Change and Urban Disaster Risks

Several studies mention global warming, which, due to the increase in greenhouse gases, is causing

Figure 23. Model of impact of climate change on water supply



the melting of glaciers in the tropical Andes and reducing the flow of rivers of glacial origin. This reduces the availability of fresh water, the main source for the consumption of the population, farming and hydropower generation, among other uses, and produces water scarcity. This shortage is exacerbated by rapid population growth, creating a social crisis (Lagos, 2013; Magrin et al., 2007; MINAM, 2010; Sadoff et al., 2010).

The study on the vulnerability of cities to climate change as regards drinking water and sanitation, conducted by the Peruvian Society of Planners in 2011, pays particular attention to the vulnerability of Service Providing Companies (EPS), in a country with enormous contrasts and significant heterogeneity as regards the effects of climate change (Figure 23). The occurrence of natural phenomena has a negative impact on the water supply, reflected in i) Water of poorer quality at the source, and ii) Lower water availability.

According to SUNARP's analysis and weighting, the three EPSs most vulnerable to climate change in Peru are Chavin EPS, the EPSs of Utcubamba and Bagua Grande (EPSSMU SRL) and Chiclayo (EPSEL).

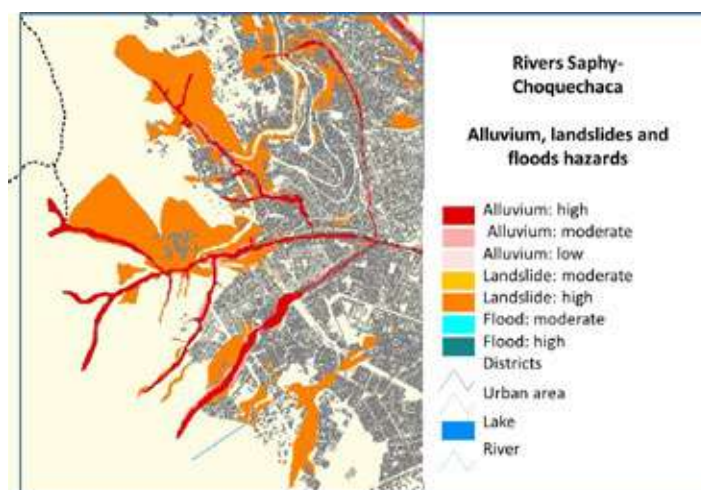
Ice in the Cordillera Blanca will probably disappear in the short term. That means that over the next three to 15 years, drastic climatic changes may take place that will endanger drinking water. Water networks are also vulnerable to extreme events, landslides and floods.

This is borne out by the following three examples. They involve the case of Cusco in response to exceptional rainfall, as in February 2010, when rains caused losses of 680 million soles and affected more than 35,000 residents; the case of Chicón, a dangerous glacier that threatens the resort town of Urubamba; and the case of Iquitos during the great flood of 2012.

6.1. Cusco, the City and its Risks

Located in the upper reaches of the River Huatanay in the southeastern Andes of Peru, 3,399 meters above sea level, the city of Cusco, the Archeological Capital of America, is the seventh largest city in the country with 420,137 inhabitants in 2014. Continuous migrations from the countryside has created a periphery of slums, many of which are located in areas of geological risk. Likewise,

Figure 24. Map of geotechnical risks in the Southwest Sector of Cusco



Source: Carlotto, Víctor et al., 2010.

riverbanks and streambeds were occupied, without considering the periods of maximum rainfall that might affect them. Consequently, rapid population growth and the consequent urban expansion have increased exposure to danger, resulting in annual disasters in the rainy season, especially in 2010, due to the heaviest rains in the past 50 years.

The city of Cusco and the valley of Huatanay are subject to a number of external geodynamic processes, where water plays a major role. This is compounded by other factors such as the existence of plains or terraces, steep slopes, and a varied lithological composition. These conditions coupled with urban explosion, show a city at risk of geodynamics, with floods, landslides and mudslides.

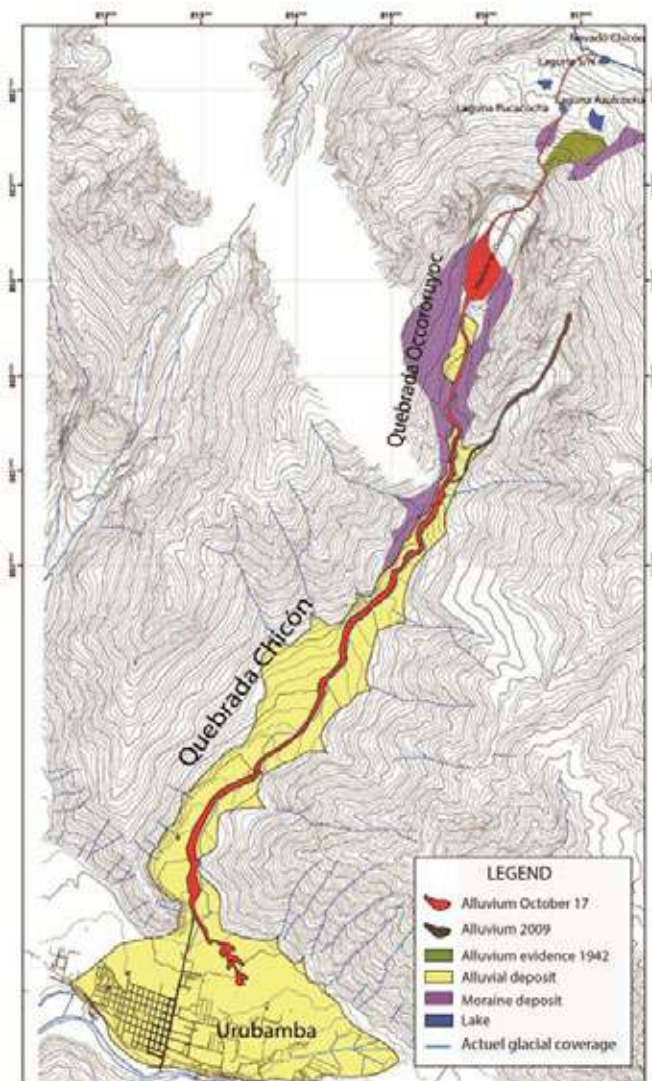
For example, due to heavy rains, landslides are reactivated or new ones are created, especially where land is of poor quality. These landslides may in turn result in the damming of stream beds and therefore silting, as happened in Huamancharpa, and the Saphy stream, which poses a great danger to the historic city center.

In response to an explosive urban sprawl, characterized by the occupation of areas with unstable slopes and ravines and river banks at risk of floods, mudslides and landslides, the Association of Municipalities and the Guamán Poma de Ayala Center developed a hazard map to improve risk management (Figure 24).

6.2 Dangerous Glaciers and Cities, the Case of the Nevado de Chicón and the City of Urubamba

At the heart of the Sacred Valley of the Incas, 2,900 masl, the city of Urubamba, with 10,741 inhabitants (2014), is located in the middle of several archaeological sites (Machu Picchu, Pisac, Moray, Cusco) and the snow-capped Chicón mountain. It enjoys an exceptional climate and landscapes, which, together with its location, makes it one of the most attractive cities in the country and a major tourist hub.

Figure 25. Alluvial events that affected the town of Urubamba (during the red mudslide of October 17, 2010)



Source: Carlotto, 2010.

The town of Urubamba is located on the right bank of the Vilcanota River, built on two alluvial cones of the Chicón and Pumahuanca streams. The Urubamba River valley separates the highlands to the south of the mountain range located in the north. The snow-capped mountain Chicón is located in this mountain range, with altitudes of over 5,300 meters. This mountain is the source of two major streams, the Chicón and the Pumahuanca, where there have been numerous landslides, while alluvial cones have been formed at the point where they flow into the Vilcanota River. Historical records show that the Palace of Wayna Capac, encompassing the complex of the agricultural platforms of Quespihuanca, is built on these old alluvial deposits in the alluvial cone of Chicón. On the other hand, old alluvial deposits from the adjacent Pumahuanca stream cover the material that slid off Yahuarmaqui Hill, which dammed the Vilcanota River in 1678. In recent times, mudslides occurred in the Chicón gorge in 1942 and 2010.

The Chicón mountain is about five kilometers long in a NW-SE direction, with an average width of less than one kilometer. This mountain shows strong evidence of glacial retreat—at least since 1963—with an average of 20 to 25 m in 10 years, although in recent years this has been nearly 50 m. Glacial retreat is accompanied by the detachment of ice blocks from the edges of the mountain. When the blocks fall into nearby lagoons, they cause floods and mudslides such as the one that occurred in 1942 and on October 17, 2010, which affected the city of Urubamba. Although the 1942 flood was large in comparison with the one in 2010, in both cases over 80% of the silt was trapped in a bucket or natural depression known as Occororuyoc Plain and only a minor part reached the city. In 2010, it affected approximately 300 dwellings, flooded farmland and affected over 1,200 people.

Driven by climate change, the retreat of the snow-capped mountain of Chicón produces overflows, leading in turn to mudslides. Due to the topography, they are cushioned downstream by the Occororuyoc depression, which traps the silt, prevents catastrophes and makes Urubamba a city with a low to medium risk of mudslides of glacial origin. However, a major earthquake could cause

a large mass of ice to break off and produce more alluvium. Glaciers should therefore be monitored and early warning systems established as priority measures, while the Chicón River should be broadened in the section passing through the city (Figure 25).

6.3 Flooding in the City of Iquitos, 2012

The capital of the Peruvian Amazon, with 432,476 inhabitants (2014), Iquitos lies between the Nanay, Itaya and Amazon rivers and follows the rhythm of fluvial dynamics (Tuukki et al., 1996). On March 12, 2012 the level of the Amazon River exceeded 117 masl, and was declared a Hydrological Red Alert by the National Meteorology and Hydrology Service (SENAMHI). During the third week of March, floods in the city of Iquitos exceeded expected levels. On April 5, the Amazon River broke its previous record by 4 cm, reaching 118.62 masl. Substantial damage was caused by the exceptional rainfall and subsequent flooding.

The number of cases of acute respiratory infections, acute diarrheal diseases, febrile syndrome, parasitosis, leptospirosis increased, continuing even as the flood waters began to subside. Until the 36th epidemiological week, five deaths and 18,206 cases of the following diseases had been reported: 15,537 (85.34%) vivax, 2,666 (14.64%) falciparum, 1 (0.01%) malaria and 1 (0.01%) mixed. A total of 9,974 more cases were recorded than during the same period in 2011, equivalent to an increase of 121.2% (PAHO/WHO, 2013).

Figure 26. Iquitos underwater, April 2012



Source: <http://cde.elcomercio.pe/66/ima/o/o/4/6/7/467607.jpg>

Likewise, according to the April 24, 2012 report by the National Superintendence of Sanitation Services (SUNASS), the following was observed in the city of Iquitos:

- Water shortages in some of the districts of Punchana and San Juan Bautista.
- Floods due to the sharp rise in river levels in the city of Iquitos, which affected 45,262 inhabitants in Belén, San Juan and Punchana.
- Suspension of the water supply in peripheral areas affected by the floods to prevent contamination of the system in the rest of the city.
- 9,410 connections affected (15.81% of total).
- Collapse of 3,858 or 10.18% of domestic sewerage connections.
- Impact on water and sewerage network improvement works.

7. Conclusions and Recommendations

Although the institutional framework of the sector is fairly well established, since it clearly distinguishes between the importance of designing policies for service regulation and delivery,¹ it has yet to deal with the problem of weak coordination between the authorities at the central level, and between these and other levels of government as well as certain gaps (Marmanillo, 2006). Conventional water management in urban areas has failed to address the key challenges of RMLC and large, medium and small cities. Generally speaking, water supply, sanitation and stormwater management has not been undertaken in a coordinated manner. Neither town planning nor urban development have managed to integrate the various infrastructure components of urban water management (water supply, wastewater, dry sanitation, storm drain and solid waste systems) (Tucci, 2010).

Thus, an Integrated Urban Water Management System (GIAU) that encompasses all water sources within the urban catchment area (surface water, ground water, storm water, desalinated water, transferred water and virtual water) must be developed. The GIAU should include plans for matching water supplies of different qualities with water uses based upon the qualities needed serve those uses. In developing the plans it will be essential to treat the elements of storage, distribution, treatment, recycling and disposal in

an integrated fashion and as part of the water cycle rather than as separate and independent elements. Plans should include measures to protect and conserve water at the source. Effective governance that includes meaningful stakeholder participation will also contribute to the sustainability of water management regimes and to water security. Integrated Urban Water Management has become an issue on the political agenda that can no longer be postpone. It requires institutional strengthening, continuity in processes, sectoral and transdisciplinary vision and well-trained human resources combined with responsible participation.

In this respect, a process of water culture must be implemented at schools, colleges and universities. These studies centers are places where one not only learns how to use, reuse and recycle water but also the benefits they entail for the community. Lastly, all cities, where peripheries of poverty grow and gaps are accentuated between those with and without access to services, and which thrive on ecosystems, fields and natural areas, urgently need to make their inhabitants aware of the new water culture, which requires building a new foundation based on a change in the scale of values, incorporating the value of the other and all the others, the value of otherness, of ecosystems and the value of life since the culture of water is the culture of life itself.

1. The first group are assigned to the Ministry of Housing, Construction and Sanitation (MVCS); the second to the (SUNASS) regulating body; and third to the EPS, municipalities and/or user boards.

8. References

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9. Acronyms

ANA:	National Water Authority
ANC:	National Academy of Sciences of Peru
BOT:	Build, Operation, Transfer
CIGA-PUCP:	Center for Research in Applied Geography at the Pontificia Universidad Católica del Perú
EPS:	Services Provider Company
GWP:	Global Water Partnership
IANAS:	InterAmerican Network of Academies of Sciences
IMP:	Metropolitan Planning Institute
INDECI:	National Institute of Civil Defense
INEI:	National Institute of Statistics and Informatics
INS:	National Institute of Health
JICA:	Japan International Cooperation Agency.
MINAM:	Ministry of Environment
MINSA:	Ministry of Health
MML:	Metropolitan Municipality of Lima
WHO:	World Health Organization
PAHO:	Pan American Health Organization
PTAR:	Wastewater Treatment Plant
RC:	Callao Region
RML:	Metropolitan Lima Region
RMLC:	Lima-Callao Metropolitan Region
SEDAPAL:	Lima Potable Water and Sewerage Service
SENAMHI:	National Meteorology and Hydrology Service
SUNARP:	National Public Records Superintendence
SUNASS:	National Sanitation Services Superintendence